

# AN ULTRASONIC-MOTOR CONTROL SYSTEM

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

5 The present invention relates to an ultrasonic-motor control system which controls the drive frequency of a voltage applied to piezoelectric ceramic elements of an ultrasonic motor.

### 2. Description of the Related Art

10 In rotary disc type ultrasonic motors, a stator is composed of an elastic body and piezoelectric ceramic elements which are adhered to the elastic body. The piezoelectric ceramic elements are polarized in the direction of the thickness thereof to thereby cause  
15 alternate expansion and shrinkage as voltage is applied. This causes bending oscillation at the surface of the elastic body. As the different voltage phases (SIN and COS waves) are applied to each electrode of the piezoelectric ceramic elements, the resulting waves are  
20 combined to form a progressive wave (traveling wave) on the surface of the elastic body. With pressure applied on the rotor, rotational motion in the opposite direction of the progressive wave is generated as a result of frictional force between the stator and the rotor. In  
25 this type of ultrasonic motor, it is known that the drive

efficiency of the motor improves as the rotational speed becomes maximum if the motor is driven at the resonance frequency thereof.

Accordingly, in the case of driving the ultrasonic  
5 motor with the resonance frequency, the drive frequency of the ultrasonic motor is conventionally controlled in the following manner: a starting frequency is set to be sufficiently higher than the resonance frequency of the ultrasonic motor, and subsequently the drive frequency  
10 is gradually decreased until it reaches the resonance frequency. Upon reaching the resonance frequency, the drive frequency is fixed, and is finely adjusted so as to maintain the resonance frequency. This control is performed because the resonance frequency (i.e., the  
15 optimum drive frequency) of the ultrasonic motor varies due to a variation in the ambient temperature and/or a variation in the load acting on the ultrasonic motor. In addition, the drive frequency of the ultrasonic motor needs to be decreased gradually from a sufficiently high  
20 frequency on the assumption that the resonance frequency would shift toward the high frequency side due to some cause.

However, in the case where resonance frequency shifts toward the low frequency side in a normal state  
25 or due to some cause, it takes a long time before the

ultrasonic motor starts rotating if the sweep operation  
of the drive frequency of the ultrasonic motor starts from  
a sufficiently high frequency in a conventional fashion.  
This becomes a leading cause of a substantial delay in  
5 the response of the ultrasonic motor.

#### SUMMARY OF THE INVENTION

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An object of the present invention is to provide an  
ultrasonic-motor control system which makes it possible  
10 to ensure a quick response and stable operation of an  
ultrasonic motor even if the resonance frequency thereof  
varies.

To achieve the object mentioned above, according to  
an aspect of the present invention, an ultrasonic-motor  
15 control system is provided, including an ultrasonic motor,  
a controller which starts the ultrasonic motor by changing  
a drive frequency of the ultrasonic motor from an initial  
drive frequency, a calculation device which calculates  
an initial drive frequency data based on a drive frequency  
20 at the commencement of rotation of the ultrasonic motor,  
and a setting device which sets the initial drive  
frequency based on the initial drive frequency data at  
a subsequent commencement of driving of the ultrasonic  
motor.

25 The controller can start the ultrasonic motor by

reducing a drive frequency of the ultrasonic motor from an initial drive frequency.

Preferably, the ultrasonic-motor control system further includes a frequency data storing device in which a drive frequency at the commencement of rotation of the ultrasonic motor is stored as starting frequency data each time the ultrasonic motor starts. The calculation device calculates an average of all the starting frequency data stored in the frequency data storing device, and calculates the initial drive frequency data using the average.

In an embodiment, the frequency data storing device stores a resonance frequency data of the ultrasonic motor; and the calculation device utilizes the resonance frequency data to calculate a value which is added to the average in order to obtain the initial drive frequency data.

In an embodiment, each time a rotational speed of the ultrasonic motor reaches a maximum rotational speed, the frequency data storing device stores a drive frequency as the resonance frequency data.

Preferably, the initial drive frequency data is greater than the average by a predetermined ratio.

In an embodiment, the setting device sets the initial drive frequency to a maximum value in a

controllable frequency range of the controller in the case where none of the starting frequency data is stored in the frequency data storing device.

In an embodiment, in the case where the ultrasonic  
5 motor does not start though the controller decreases the drive frequency of the ultrasonic motor to a minimum frequency in a controllable frequency range of the controller, the controller clears all the starting frequency data stored in the frequency data storing device,  
10 and the setting device sets the initial drive frequency to a maximum value in a controllable frequency range of the controller.

Preferably, the ultrasonic-motor control system further includes a rotational speed determining device  
15 which determines a rotational speed of the ultrasonic motor, upon a predetermined time elapsing from the commencement of rotation of the ultrasonic motor, each time the ultrasonic motor starts; a rotational speed storing device in which the rotational speed is stored  
20 as speed data, wherein at least a previous speed data and a current speed data are stored in the rotational speed storing device; and a determining device which determines whether a speed-data difference between the previous speed data and the current speed data is one of equal to  
25 and greater than a predetermined value. The controller

clears all the starting frequency data stored in the frequency data storing device in the case where the determining device determines that the speed-data difference is one of equal to and greater than the  
5 predetermined value.

In an embodiment, the ultrasonic-motor control system further includes a temperature sensor for sensing an ambient temperature of the ultrasonic motor before each time the controller starts the ultrasonic motor; and a  
10 temperature data storing device in which the ambient temperature is stored as temperature data, wherein at least a previous temperature data and a current temperature data are stored in the temperature data storing device. The determining device determines  
15 whether a temperature-data difference between the previous temperature data and the current temperature data is one of equal to and greater than a predetermined value, wherein the controller clears all the starting frequency data stored in the frequency data storing device  
20 in the case where the determining device determines that the temperature-data difference is one of equal to and greater than the predetermined value.

In an embodiment, the setting device sets the initial drive frequency to a maximum value in a  
25 controllable frequency range of the controller in the case

where none of the starting frequency data is stored in the frequency data storing device.

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Preferably, the ultrasonic-motor control system includes a temperature sensor for sensing an ambient temperature of the ultrasonic motor before each time the controller starts the ultrasonic motor; a temperature data storing device in which the ambient temperature is stored as temperature data, wherein at least a previous temperature data and a current temperature data are stored in the temperature data storing device; and a determining device which determines whether a difference between the previous temperature data and the current temperature data is one of equal to and greater than a predetermined value. The controller clears all the starting frequency data stored in the frequency data storing device in the case where the determining device determines that the difference is one of equal to and greater than the predetermined value.

20 In an embodiment, the setting device sets the initial drive frequency to a maximum value in a controllable frequency range of the controller in the case where none of the starting frequency data is stored in the frequency data storing device.

25 In an embodiment, the initial drive frequency data is stored in the frequency data storing device.

In an embodiment, the frequency data storing device stores the current starting frequency data and a predetermined number of previous starting frequency data.

5 In an embodiment, the setting device compares the calculated initial drive frequency with a maximum drive frequency in a controllable frequency range of the controller, and the setting device sets the initial drive frequency to the maximum drive frequency in the case where  
10 the calculated initial drive frequency is higher than the maximum drive frequency.

Preferably, the ultrasonic-motor control system is incorporated in a camera system.

The present disclosure relates to subject matter  
15 contained in Japanese Patent Application No.2001-1462 (filed on January 9, 2001) which is expressly incorporated herein by reference in its entirety.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 The present invention will be described below in detail with reference to the accompanying drawings in which:

Figure 1 is a block diagram of an embodiment of an ultrasonic-motor control system, which is incorporated  
25 in a camera system, according to the present invention;



Figure 2 is a flow chart for a main process of the ultrasonic-motor control system shown in Figure 1;

Figure 3 is a flow chart for a drive process shown in Figure 2;

5 Figure 4A is the first half of a flow chart for ultrasonic motor start process shown in Figure 3;

Figure 4B is the latter half of the flow chart for ultrasonic motor start process shown in Figure 3;

10 Figure 5 is a flow chart for a starting frequency storing and average value calculating process shown in Figure 4B;

Figure 6 is a flow chart for an initial drive frequency calculation process shown in Figure 3;

15 Figure 7 is a graph showing a variation in the rotational speed of the ultrasonic motor in time sequence according to the present embodiment of the ultrasonic-motor control system, and a variation in the rotational speed of the ultrasonic motor in time sequence according to a conventional control system;

20 Figure 8A is a graph showing the correlation between the drive frequency of the ultrasonic motor and the number of revolutions in different ambient temperatures;

25 Figure 8B is a graph showing the correlation between the drive frequency of the ultrasonic motor and an oscillation voltage in different ambient temperatures;

Figure 9 is a flow chart for another embodiment of a main process of the ultrasonic-motor control system shown in Figure 1;

Figure 10 is a flow chart for a drive process shown  
5 in Figure 9;

Figure 11A is the first half of a flow chart for ultrasonic motor start process shown in Figure 10; and

Figure 11B is the latter half of the flow chart for ultrasonic motor start process shown in Figure 10.

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#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows an embodiment of an ultrasonic-motor control system, which is incorporated in a camera system, according to the present invention. In this embodiment,  
15 the drive frequency of a voltage (i.e., the frequency of a drive frequency signal) applied to an ultrasonic motor (USM) 10 for driving an AF lens group of an autofocus camera system (i.e., the drive frequency of the ultrasonic motor 10 for driving the AF lens group) is controlled by  
20 the ultrasonic-motor control system.

Although the structure of the ultrasonic motor 10 is not shown in the drawings, the ultrasonic motor 10 is provided with a stator which is composed of an elastic body and piezoelectric ceramic elements which are adhered  
25 to the elastic body, and a rotor (dynamic body) which is

pressed against the stator. If the voltage having two phases with spatial and phase difference of 90 degrees is applied to the piezoelectric ceramic elements, a progressive wave of flexural vibration is produced, and rotational motion in the opposite direction of the progressive wave is generated as a result of frictional force between the stator and the rotor.

The ultrasonic motor 10 is provided with a sensor electrode S. The sensor electrode S detects an oscillation voltage  $V_D$  whose amplitude is proportional to that of the stator of the ultrasonic motor 10 when a flexural vibration is produced on the stator. Namely, the ultrasonic motor 10 outputs a signal (the oscillation voltage  $V_D$ ) whose oscillation frequency corresponds to the drive frequency of the ultrasonic motor 10 from the sensor electrode S. Figure 8A shows a graph showing the correlation between the drive frequency of the ultrasonic motor 10 and the number of revolutions (rpm) of the ultrasonic motor 10, while Figure 8B shows a graph showing the correlation between the drive frequency of the ultrasonic motor 10 and the oscillation voltage  $V_D$ .

The present embodiment of the ultrasonic-motor control system is provided with a lens CPU (controller/calculation device/setting device/rotational speed determining device/determining device) 20. The lens CPU

20 communicates with a camera CPU 30, and operates in accordance with control signals input from the camera CPU 30. Such control signals include a signal which defines a drive commencement command and a signal which defines the amount of driving of the ultrasonic motor 10 (i.e., the number of drive pulses of the ultrasonic motor 10).

The lens CPU 20 is provided therein with a ROM 20d in which various control programs are stored, a RAM 20c in which various control data are temporarily stored, an A/D conversion input port 20a and a counter 20b. The lens CPU 20 operates with power supplied from a power source Vcc of the camera system. The A/D conversion input port 20a is connected to the junction of a thermistor Rt and a resistor R. The thermistor Rt serves as a temperature sensor, and the resistance value of the thermistor Rt varies in accordance with a variation in the ambient temperature. The lens CPU 20 detects the ambient temperature in accordance with the input level of the A/D conversion input port 20a. The counter 20b counts down each time it inputs a pulse which is output from a pulse encoder 21 in accordance with the amount of rotation of the ultrasonic motor 10. The lens CPU 20 controls the deceleration and the stopping of the ultrasonic motor 10 in accordance with the value of the counter 20b. At the same time, the lens CPU 20 determines

the rotational speed of the ultrasonic motor 10 in accordance with the amount of variation in the value of the counter 20b within a predetermined period of time. The lens CPU 20 controls the acceleration driving and the constant-speed driving of the ultrasonic motor 10 in accordance with the oscillation voltage  $V_D$ .

A ultrasonic motor drive circuit 22 and an EEPROM (frequency data storing device/rotational speed storing device/temperature data storing device) 23 serving as a non-volatile memory are connected to the lens CPU 20. The ultrasonic motor drive circuit 22 supplies an AC signal having a frequency corresponding to a command issued by the lens CPU 20 to the ultrasonic motor 10. The EEPROM 23 serves as memory for storing various data therein. The lens CPU 20 reads and writes data from and to the EEPROM 23 as needed.

The general outline of the motor-drive controlling operations performed by the lens CPU 20 will be hereinafter discussed based on the above described structure of the ultrasonic-motor control system.

The lens CPU 20 supplies a voltage having a drive frequency corresponding to an initial drive frequency data finit of the ultrasonic motor 10, and gradually decreases the drive frequency from the initial drive frequency. At the moment the ultrasonic motor 10 starts

rotating, the current starting frequency data  $f_{scur}$  which is the drive frequency at the commencement of rotation of the ultrasonic motor 10 is stored in the EEPROM 23, and subsequently the lens CPU 20 further decreases the drive frequency to accelerate the ultrasonic motor 10. Subsequently, immediately after the oscillation voltage  $V_D$  detected by the sensor electrode S reaches a prescribed voltage, the drive frequency at this time is stored as a resonance frequency data  $f_r$  in the EEPROM 23 to drive the ultrasonic motor 10 at the maximum speed at the stored frequency. Subsequently, immediately after the ultrasonic motor 10 is driven by a predetermined amount of rotation, the speed of the ultrasonic motor 10 is reduced to stop the ultrasonic motor 10, and then the initial drive frequency data  $f_{init}$  for the subsequent driving operation of the ultrasonic motor 10 is determined in accordance with starting frequency data  $f_s[n]$  and the resonance frequency data  $f_r$ . It should be noted that "n" of the aforementioned " $f_s[n]$ " is a variable which indicates the number of starting frequency data stored in the EEPROM 23. The determined initial drive frequency data  $f_{init}$  is stored in the EEPROM 23 so as to be read out therefrom at the subsequent driving operation of the ultrasonic motor 10. With the initial drive frequency data  $f_{init}$  stored in EEPROM 23, the lens CPU 20 controls

the driving of the ultrasonic motor 10 in the above described manner.

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The main characteristic of the present embodiment is the calculation (setting) of the initial drive frequency data finit. Namely, the initial drive frequency data finit is determined based on the previous data stored in the EEPROM 23, which is greater than the resonance frequency of the ultrasonic motor 10 so that the starting time of the ultrasonic motor 10 becomes minimal. According to the determination of the initial drive frequency data finit, the ultrasonic motor 10 can be started at drive frequency higher than the resonance frequency, and also can be driven with stability after startup of the ultrasonic motor 10. In addition, a reduction in the starting time of the ultrasonic motor 10 makes it possible to improve the response of the ultrasonic motor 10. Although it is known in the art that the performance of an ultrasonic motor deteriorates drastically if the drive frequency becomes lower than the resonance frequency, such a problem never occurs in the present embodiment.

In the present embodiment, if the variation of the ambient temperature and/or the load acting on the ultrasonic motor 10 has become greater than a predetermined value since the previous driving time, all

the data on the ultrasonic motor 10 such as the starting frequency data  $fs[n]$  and the initial drive frequency data  $finit$  which are stored in the EEPROM 23 are cleared because it is considered that the resonance frequency of the ultrasonic motor 10 may have varied. In addition, if no data on the ultrasonic motor 10 is in the EEPROM 23, the initial drive frequency data  $finit$  is set to the maximum value in consideration of the case where the resonance frequency of the ultrasonic motor 10 may shift to the high frequency side. This makes it possible to ensure the startup and the stable driving of the ultrasonic motor 10 even if the resonance frequency thereof varies.

The motor-drive controlling operations performed by the lens CPU 20 will be further discussed in detail with reference to the flow charts shown in Figures 2 through 6. Main process shown in Figure 2 starts immediately after the power of the camera is turned ON. In the ON state of the power of the camera, operations at steps S13 through S19 are repeated.

In the main process, firstly all the starting frequency data  $fs[n]$  stored in the EEPROM 23 are cleared ( $n=0$ ), while the initial drive frequency data  $finit$  is set to the maximum value in a predetermined controllable frequency range of the lens CPU 20 (step S11). The initial drive frequency data  $finit$  is a drive frequency



of a voltage (drive voltage) when the lens CPU 20 starts supplying the voltage to the piezoelectric ceramic elements of the ultrasonic motor 10.

Subsequently, communications are carried out  
5 between the lens CPU 20 and the camera CPU 30 (step S13),  
and subsequently it is determined whether a command to start the ultrasonic motor 10 has been input to the lens CPU 20 from the camera CPU (step S15). If a command to start the ultrasonic motor 10 has not yet been input (if  
10 NO at step S15), control returns to step S13 to repeat the operations at steps S13 and S15 until a command to start the ultrasonic motor 10 has been input to the lens CPU 20. If a command to start the ultrasonic motor 10 has been input (if YES at step S15), the counter 20b is  
15 set to the number of drive pulses of the ultrasonic motor 10 which has been set in the camera body (step S17). Subsequently, a drive process ("DRIVE" shown in Figure 3) is performed (step S19).

The drive process will be hereinafter discussed in  
20 detail with reference to the flow chart shown in Figure 3. In this process, firstly a ultrasonic motor start process ("USM START" shown in Figures 4A and 4B) is performed to start the ultrasonic motor 10 (step S21). Upon the commencement of rotation of the ultrasonic motor  
25 10, the drive frequency is further decreased to accelerate

the ultrasonic motor 10 (step S23). In the driving operation of the ultrasonic motor 10, the drive frequency of the ultrasonic motor 10 is gradually reduced from the initial drive frequency data finit. Subsequently, upon the drive frequency sweep operation starting, CPU 20 determines that the ultrasonic motor 10 has started rotating when the output of the pulse encoder 21 is first detected.

Subsequently, the drive frequency at the moment the oscillation voltage  $V_D$ , which is detected by the sensor electrode S, reaches a prescribed voltage is stored as a resonance frequency data fr in the EEPROM 23 (S25), and the drive frequency is kept at the stored resonance frequency in order to drive the ultrasonic motor 10 at a constant speed (step S27). Each of the accelerating driving operation and the constant driving operation at steps S23 and S27 are controlled in accordance with the oscillation voltage  $V_D$ , but will not be hereinafter discussed in detail since they have no direct bearing on the present invention. Subsequently, upon completion of driving of the ultrasonic motor 10 by a predetermined period of time or a predetermined number of pulses at a constant speed, the rotational speed of the ultrasonic motor 10 is reduced in accordance with the value of the counter 20b to stop the ultrasonic motor 10 at the time

the value of the counter 20b reaches 0 (step S29). Subsequently, an initial drive frequency calculation process ("INITIAL DRIVE FREQUENCY CALCULATION" shown in Figure 6) is performed (step S31). In this process, the  
5 initial drive frequency data finit for the subsequent driving operation of the ultrasonic motor 10 is calculated and stored in the EEPROM 23. After the initial drive frequency calculating process is performed, control returns to the main process.

10 The ultrasonic motor start process will be hereinafter discussed in detail with reference to the flow chart shown in Figures 4A and 4B. In the ultrasonic motor start process, firstly the current ambient temperature is detected from the input level of the A/D conversion  
15 input port 20a (step S41), and is stored in the EEPROM 23 (step S43). Subsequently, it is determined whether the variable n, which indicates the number of the starting frequency data stored in the EEPROM 23, is greater than zero (step S45). If the variable n is not greater than  
20 zero (if NO at step S45), the initial drive frequency data finit is set to the maximum in the controllable frequency range (step S47), and control proceeds to step S57. If the variable n is greater than zero (if YES at step S45), the previously detected ambient temperature and the  
25 current detected ambient temperature are read out of the

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EEPROM 23 to determine whether the difference between the absolute value of the previously detected ambient temperature and the absolute value of the current detected ambient temperature is equal to or greater than a predetermined value (CONST) (step S49). If the  
5 above-mentioned difference is smaller than the predetermined value (if NO at step S49), the initial drive frequency data finit is read from the EEPROM 23 to be set (step S51), and control proceeds to step S57. In this  
10 case, the driving of the ultrasonic motor 10 is configured to start at the initial drive frequency which has been determined at the previous driving of the ultrasonic motor 10 because the current environmental factors such as ambient temperature of the current driving of the  
15 ultrasonic motor 10 are considered substantially identical to the previous environmental factors. This control makes it possible to start driving the ultrasonic motor 10 at a drive frequency which is close to and higher than, the resonance frequency of the ultrasonic motor 10,  
20 and also to reduce the starting time of the ultrasonic motor 10. On the other hand, if the above-mentioned difference is equal to or greater than the predetermined value (if YES at step S49), this means that the ambient temperature has varied substantially from the time of the  
25 previous driving of the ultrasonic motor 10. In this case,

it is possible that the resonance frequency of the ultrasonic motor 10 may vary substantially. Accordingly, if the above-mentioned difference is equal to or greater than the predetermined value (if YES at step S49), the initial drive frequency data finit is set to the maximum value in the controllable frequency range (step S53), and subsequently all the starting frequency data fs[n] stored in the EEPROM 23 are cleared (n=0) (step S55). Subsequently control proceeds to step S57.

10       At step S57 a voltage having drive frequency corresponding to the initial drive frequency data finit is applied to the ultrasonic motor 10 via the ultrasonic motor drive circuit 22. Subsequently, it is determined whether the ultrasonic motor 10 has started rotating according to whether or not the output of the pulse encoder 21 has been detected (step S59). It is determined that the ultrasonic motor 10 has started rotating when the output of the pulse encoder 21 is firstly detected after a voltage is applied to the ultrasonic motor 10. If the

15       ultrasonic motor 10 has not started rotating yet (if NO at step S59), it is determined whether the current drive frequency is the minimum frequency in the controllable frequency range (step S61). If the current drive frequency is not the minimum frequency (if NO at step S61),

20       the drive frequency is decreased by a predetermined value

25

(step S63) and control returns to step S59. Accordingly, the operations at steps S59, S61 and S63 are repeated to perform the drive frequency sweep operation until the drive frequency is a minimum value as long as it is determined at step S59 that the ultrasonic motor 10 has not yet started rotating. If the drive frequency reaches the minimum frequency in the controllable frequency range before the ultrasonic motor 10 starts rotating (if YES at step S61), all the starting frequency data fs[n] stored in the EEPROM 23 are cleared (n=0) (step S65), and subsequently the current starting frequency fscur is set to the maximum frequency in the controllable frequency range (step S67). Subsequently, control proceeds to step S77.

15 Immediately after the ultrasonic motor 10 starts rotating (if YES at step S59), the current rotational speed of the ultrasonic motor 10 is determined from a variation in the value of the counter 20b within a predetermined amount of time (step S69). Subsequently  
20 the determined current rotational speed is stored in the EEPROM 23 (step S71), and it is determined whether the variable n is greater than zero (step S73). If the variable n is greater than zero (if YES at step S73), the previously detected ambient temperature and the current  
25 detected ambient temperature are read out of the EEPROM

23 to determine whether the difference between the absolute value of the previous speed and the absolute value of the current speed is equal to or greater than a predetermined value (CONST) (step S75). If the above-mentioned difference is equal to or greater than the predetermined value (if YES at step S75), this means that the load acting on the ultrasonic motor 10 has varied substantially. In this case, it is possible that the resonance frequency of the ultrasonic motor 10 may vary substantially. Accordingly, if the above-mentioned difference is equal to or greater than the predetermined value (if YES at step S75), all the starting frequency data  $fs[n]$  stored in the EEPROM 23 are cleared ( $n=0$ ) (step S65), and subsequently the current starting frequency  $fscur$  is set to the maximum frequency in the controllable frequency range (step S67). Thereafter, control proceeds to step S77. If the variable  $n$  is equal to or smaller than zero (if NO at step S73) or if the above-mentioned difference is smaller than the predetermined value (if NO at step S75), control proceeds to step S77 since the previous data can be utilized. At step S77, a starting frequency storing and average value calculating process ("STARTING FREQUENCY STORING & AVERAGE VALUE CALCULATION" shown in Figure 5) is performed, and control returns to the drive process shown in Figure

3.

The starting frequency storing and average value calculating process that is performed at step S77 will be hereinafter discussed in detail with reference to the flow chart shown in Figure 5. In this process, firstly it is determined whether the variable n, which indicates the number of the starting frequency data stored in the EEPROM 23, is equal to or greater than five (step S81). In this particular embodiment, the maximum number of data on the starting frequency which can be stored in the EEPROM 23 is five. Namely, it is determined at step S81 whether the starting frequency data have already been stored up to the maximum number of data in the EEPROM 23.

If the variable n is smaller than five (if NO at step S81), the variable n is increased by one (step S83). Subsequently, the current starting frequency data fscur is stored as the starting frequency data fs[n] (i.e., the "n"th starting frequency data fs) (step S87), and subsequently an average starting frequency data fsavr is calculated from all the starting frequency data stored in the EEPROM 23 (step S89). Thereafter control returns.

If the variable n is equal to or greater than five (if YES at step S81), the oldest (first) starting frequency data fs[1] stored in the EEPROM 23 is cleared while the second, third, fourth and fifth starting



frequency data fs[2], fs[3], fs[4] and fs[5] are re-stored  
as the first, second, third and fourth starting frequency  
data fs[1], fs[2], fs[3] and fs[4] in the EEPROM 23,  
respectively, so as to store the current starting  
5 frequency data as the fifth starting frequency data fs[5]  
in the EEPROM 23 at all times (step S85). Subsequently,  
the current starting frequency data fscur is stored as  
the starting frequency data fs[5] (step S87), and  
subsequently the average starting frequency data fsavr  
10 is calculated from all the starting frequency data stored  
in the EEPROM 23 (step S89). Thereafter control returns.

The initial drive frequency calculation process  
that is performed at step S31 will be hereinafter  
discussed in detail with reference to the flow chart shown  
15 in Figure 6. In this process, firstly the average  
starting frequency data fsavr of all the starting  
frequency data fs[n] and the resonance frequency fr are  
read from the EEPROM 23 to calculate the initial drive  
frequency data finit from the following equation:

$$20 \quad finit = fsavr + (fsavr - fr) \times 0.1 \quad (\text{step S91}).$$

Subsequently, it is determined whether the  
calculated initial drive frequency data finit is greater  
than the maximum frequency in the controllable frequency  
range (step S93). If the calculated initial drive  
25 frequency data finit is greater than the maximum

frequency in the controllable frequency range (if YES at step S93), the initial drive frequency data finit is re-set to the maximum in the controllable frequency range (step S95), and subsequently control returns. On the other hand, if the calculated initial drive frequency data finit is equal to or smaller than the maximum frequency in the controllable frequency range (if NO at step S93), control skips the operation at step S95 and therefore returns.

10       Determining the initial drive frequency data finit in the above described manner makes it possible to reduce the starting time of the ultrasonic motor 10, as compared with the conventional case where the drive frequency sweep operation is carried out from the maximum drive frequency  
15       at every time (see Figure 7).

Although the initial drive frequency data finit is calculated from the above equation " $f_{init} = f_{savr} + (f_{savr} - f_r) \times 0.1$ " in the present embodiment of the ultrasonic-motor control system, the initial drive  
20       frequency data finit can be set to a drive frequency which is greater than the average starting frequency data fsavr by a predetermined ratio, e.g., to a drive frequency of the average starting frequency data fsavr multiplied by 1.1.

25       An alternative embodiment of the motor-drive

controlling operation performed by the lens CPU 20 will be discussed in detail with reference to the flow charts shown in Figures 9 through 11B. In this alternative embodiment, the RAM 20c is used as a memory for the various operations instead of the EEPROM 23, and the EEPROM 23 is used as a back-up memory.

Figure 9 is a flow chart for the main process according to the alternative embodiment. In the main process, firstly control data is read from the EEPROM 23, and the read control data is stored in the RAM 20c. The control data includes the starting frequency data  $fs[n]$ , the average starting frequency data  $fsavr$ , the resonance frequency  $fr$ , the initial drive frequency data  $finit$ , the ambient temperature data, and the rotational speed data.

Upon the control data being stored in the RAM 20c, control proceeds to step S110. Steps S110, S130, S150, S170 and S190 correspond to steps S11, S13, S15, S17 and S19, and the description thereof are therefore omitted. Steps S160-1 and S160-2, which are not present in Figure 2, will herein be described. Control proceeds to step S160-1 from step S150 (S150, NO) when no command to start the ultrasonic motor 10 has been input to the lens CPU 20. In step S160-1, it is determined whether a predetermined time has elapsed in a state where no command has been input to the lens CPU 20. If a predetermined

time has not yet elapsed, control returns to step S130 (S160, N; S130). If a predetermined time has elapsed, the control data stored in the RAM 20c is written into the EEPROM 23, and control returns to step S130 (S160-1, 5 Y; S160-2; S130).

Figure 10 is a flow chart for a drive process shown in Figure 9, and is similar to Figure 3. In the drive process, steps S210, S230, S270, S290 and S310 correspond to steps S21, S23, S27, S29 and S31 of Figure 3. The process 10 shown in step S250, the resonance frequency data fr is stored in the RAM 20c instead of the EEPROM 23, which differs from step S25 of Figure 3.

Figures 11A and 11B are flow charts for the ultrasonic motor start process (USM Start Process) shown 15 in Figure 10, and correspond to Figures 4A and 4B. In Figure 11A, steps S410, S450, S470, S490, S510 and S530 correspond to steps S41, S45, S47, S49, S51 and S53 of Figure 4A. Likewise, in Figure 11B, steps S570, S590, S610, S630, S670, S690, S730, S750 and S770 20 correspond to steps S57, S59, S61, S63, S67, S69, S73, S75 and S77 of Figure 4B. Only steps S430 and S550 of Figure 11A differ from Figure 4A, and only steps S650 and S710 differ from Figure 4B. In step S430, the detected ambient temperature is stored in the RAM 20c instead of 25 the EEPROM 23. Furthermore, in steps S550 and S650, the

starting frequency data is cleared from the RAM 20c instead of the EEPROM 23. In step S710, the determined rotational speed is stored in the RAM 20c instead of the EEPROM 23.

5        If the control data is read from and written into the RAM 20c, as described above, the control time is faster than when the EEPROM 23 is used, and hence utilizing the RAM 20c in this way is more practical.

10        Note that when the power supply is turned off or if no operations are performed within a predetermined amount of time, since the peripheral environment can change, an embodiment can also be provided wherein all of the data is cleared. In such a case, all of the data can be stored and restored in the RAM 20c, so that the EEPROM 23 would  
15        not be necessary.

20        Although an AF lens group of a camera system is driven by the ultrasonic motor 10 in the above described embodiment of the ultrasonic-motor control system, any other elements such as a movable lens group for zooming provided in a zoom lens barrel or a movable element  
25        provided in other optical instrument can be driven by the ultrasonic-motor. The ultrasonic-motor control system according to the present invention can be used in a more effective manner if applied to an electronic instrument in which the ultrasonic motor needs to start, stop and

again start frequently.

As can be understood from the above descriptions,  
according to the ultrasonic-motor control system to which  
the present invention is applied, the ultrasonic motor  
5 can reliably be made to start rotating at a drive frequency  
higher than the resonance frequency while reducing the  
starting time of the ultrasonic motor 10. Furthermore,  
according to the ultrasonic-motor control system to which  
the present invention is applied, the ultrasonic motor  
10 can be reliably started and driven with stability even  
if the resonance frequency varies due to a variation in  
the ambient temperature and/or a variation in the load  
acting on the ultrasonic motor.

Obvious changes may be made in the specific  
15 embodiment of the present invention described herein,  
such modifications being within the spirit and scope of  
the invention claimed. It is indicated that all matter  
contained herein is illustrative and does not limit the  
scope of the present invention.